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HOME RANGE CHARACTERISTICS OF MALE COOPER'S HAWKS IN AN URBAN ENVIRONMENT

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ABSTRACT.—We monitored the movements of nine radio-tagged, adult, male Cooper's Hawks (*Accipiter cooperii*) in adjacent home ranges during the breeding seasons of 1996 or 1997 in Tucson, Arizona, to ascertain the sizes and degree of overlap of home ranges, and to assess habitat selection at two spatial scales. Size of home ranges differed among hawks (13.3–130.6 ha), but the average was small [65.5 ha ± 40.7 (SD)] compared to the size of home ranges reported for Cooper's Hawks in the literature. Home range size generally decreased with the number of years that a hawk had lived on its breeding territory. Only one pair of home ranges overlapped each other; overlap of one home range on the other in this pair was 14.2% and 10.6%. Proportions of land-use categories in home ranges varied widely among hawks, and suggested that the hawks did not select their home ranges on the basis of the categories we examined. Patterns of habitat use inside individual home ranges suggested that male hawks hunted primarily in the environments that surrounded their nests. Cooper's Hawks in Tucson feed primarily on doves [Mourning Doves (*Zenaida macroura*), Inca Doves (*Columbina inca*), and White-winged Doves (*Zenaida asiatica*)], and we speculate that the abundance of doves throughout Tucson allowed the hawks to hunt successfully in several urban environments. We also speculate that Cooper's Hawks in Tucson have relatively small home ranges because they do not need to range far from their nests to find food.
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Cooper's Hawks (*Accipiter cooperii*) generally nest in undeveloped forests and woodlands (Reynolds 1989, Rosenfield and Bielefeldt 1993), but they occasionally nest in towns and cities (Stahlecker and Beach 1979, Murphy et al. 1988, Rosenfield et al. 1995, Stewart et al. 1996, Boal and Mannan 1998). Reported densities of nesting Cooper's Hawks in undeveloped environments range from 1 nest every 671–2326 ha in the western United States (Reynolds 1989), and from 1 nest every 331–5000 ha in the eastern United States (Rosenfield et al. 1991). Estimates of nest density in some urban/suburban environments are among the highest reported. For example, Rosenfield and coworkers (1995) found a density of 1 nest every 272 ha for Cooper's Hawks in Stevens Point, Wisconsin, and Boal and Mannan (1998) found an overall density of 1 nest every 437 ha in Tucson, Arizona.

The density of nests in an area is determined largely by the density and quality of resources required for breeding (e.g., nest sites, food), with the upper limit being set by spacing behavior in territorial birds (Newton 1986). As the conditions that promote a high density of nests become more prevalent in an area, the size of individual home ranges and the amount of overlap among neighboring home ranges might change in one of two ways. First, the average size of home ranges could decrease, and overlap of neighboring home ranges might, therefore, remain about the same. Conversely, if the size of home ranges remains stable as nest density increases, overlap among neighboring home ranges might increase. It is also possible that home range size and overlap could fluctuate among different stages of the annual cycle (Newton 1986). We monitored the movements of male Cooper's Hawks during the breeding season in an urban environment where nest density was relatively high (1 nest every 362 ha) to ascertain the sizes and degree of overlap of home ranges. Because density of nests is determined in part by quality of resources, and habitat quality may vary among urban environments, we also looked for evidence of habitat selection by male Cooper's Hawks. We investigated habitat selection by assessing where Cooper's Hawks placed their home ranges relative to available urban environments (i.e., home range selection), and by assessing how Cooper's Hawks used different environments inside their home ranges (i.e., intra-home range selection; Johnson 1980).

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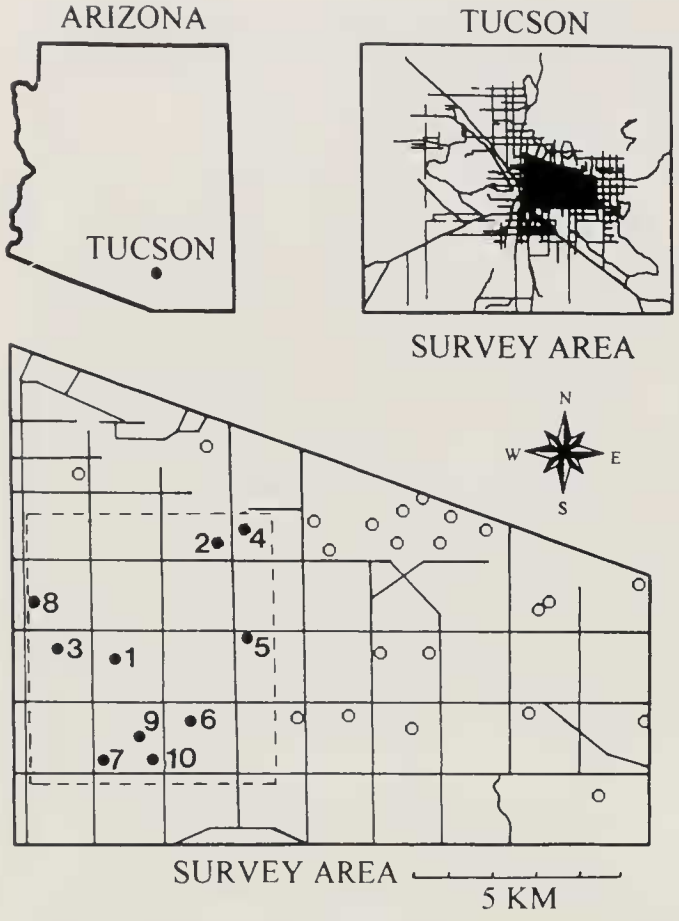

FIG. 1. Location of Tucson, Arizona (top left), the survey area within Tucson (top right, in black), and distribution of nests (● and ○) in the survey area in 1996 and/or 1997 (bottom). Solid circles indicate nests where males were captured and radio-tagged within the survey area (1 = Terra Alta, 2 = San Carlos, 3 = Himmel Park, 4 = Torino, 5 = Swanway Park, 6 = Cooper, 7 = Reid Park, 8 = Adams, 9 = Randolph North, 10 = Randolph South). The rectangular area (dashed line), which encompasses the home ranges of radio-tagged males, is 3618 ha.

STUDY AREA AND METHODS

Study area.—We studied Cooper's hawks in Tucson, Arizona (32° N, 111° W; Fig. 1). The Tucson metropolitan area encompasses approximately 70,000 ha and has a human population of about 800,000. Tucson is located in the Sonoran Desert and supports Lower and Upper Sonoran vegetation types and riparian corridors (Brown et al. 1979). Although remnants of these vegetative communities persist in Tucson, much of the natural vegetation has been removed or replaced with exotic plants.

The hawks we monitored occupied home ranges that were clustered in a 3618 ha area that was part of a larger area we had surveyed intensively for the presence of nesting Cooper's hawks (Boal and Mannan 1998; Fig. 1). Land in the area surveyed was used primarily for private residences, businesses, parks and golf courses.

Radio telemetry.—We monitored the movements of adult, male Cooper's Hawks in adjacent home ranges (Fig. 1) during the breeding seasons (March–July) of 1996 or 1997. We captured the hawks near their nests with dho gaza traps or bal-chatri traps (Bloom 1987) and attached a Holohill PD-2 transmitter (Holohill Systems, Ltd., Ontario, Canada) with a 6-month battery life to a tail feather of each hawk (Giroux et al. 1990). The transmitters weighed 3.5 g and were less than 2% of the body weight of males.

We relocated radio-tagged hawks with the homing technique (White and Garrott 1990) aided by Telonics (Telonics, Mesa, Arizona) TR-2 and TR-4 receivers with model RA-14 flexible, two-element yagi antennas. Cooper's Hawks in Tucson are acclimated to the presence of humans (Boal and Mannan 1999) and single observers could approach hawks without frightening them. Therefore, we attempted to see the hawks at each relocation. Sometimes hawks were out of sight (e.g., in a back yard), but they were close enough that their radio signal was detectable without an antenna. In such cases, the location of the hawk was estimated to be within 10 m of the point of the strongest signal. When the radio signal indicated a hawk was in a nest tree or nest grove, we stayed away from the nest and attempted to see the hawk with binoculars to reduce disturbance at the nest.

We relocated each radio-tagged hawk 5–10 times per week. We relocated hawks throughout the day and attempted to uniformly spread the relocations of each hawk among four periods (05:00–09:00, 09:00–13:00, 13:00–17:00, and 17:00–20:00 MST or darkness). Once the location of a hawk was determined, we mapped its position and recorded the general environment in which it was found (e.g., residential area, park, golf course). We stopped tracking a hawk after we recorded its location and did not relocate it again for at least 4 hours to minimize the risk of dependency between locations. We selected the 4 hour period based on the general rule that locations at times t_1 and t_2 can be considered statistically independent if the period between t_1 and t_2 is sufficient to allow the animal being followed to move from one end of its home range to another (White and Garrot 1990).

Seasonal patterns of movement for many animals correspond to biological cycles; thus, comparison of home ranges among different individuals must be done during the same periods of their cycles (Samuel and Fuller 1994). We chose to estimate home range size from early in the nesting cycle (i.e., nest building or incubation) until after the nestlings had fledged. We found that Cooper's Hawks in Tucson tended to make obvious deviations from their established home ranges about six weeks after their nestlings had fledged, probably coincident with fledglings approaching independence. The information we present is, therefore, from relocations taken from the day following tagging to six weeks post-fledging.

Analyses.—We transposed mapped locations of all hawks onto 7.5 minute series topographical maps, and then calculated Universal Transverse Mercator (UTM) coordinates and entered them into a database. We estimated size of home range for each hawk and overlap

TABLE 1. Size of home ranges (ha) for adult, male Cooper's Hawks during the breeding season in Tucson, Arizona, 1996 or 1997.

Nest	Period tracked	n[a]	100% MCP[b]	Adaptive kernal 90%	Adaptive kernal 95%	Years of residency
Terra Alta	3/23–7/4/97	97	194.6	104.7	130.6	1
San Carlos	4/12–6/28/97	71	149.3	30.6	114.8	1
Himmel Park	3/16–7/17/96	102	132.9	43.2	88.7	1
Torino	5/24–6/29/97	60	66.1	38.9	85.2	1
Swanway Park	3/11–6/29/97	93	74.4	17.2	45.6	2
Cooper	2/27–6/28/97	88	115.1	3.3	41.4	≥2
Reid Park	6/11–8/8/96	30	39.5	34.7	39.9	2
Adams	5/13–7/20/96	43	23.1	25.5	29.8	2
Randolph North	3/23–6/28/97	73	20.9	6.9	13.3	≥4
Mean			90.7	33.9	65.5	
SD			60.8	29.9	40.7	

[a] Number of relocations for each hawk.
[b] Minimum Convex Polygon.

among home ranges within a given year with the adaptive kernel method (95% isopleth; Worton 1989). We generated area-observation curves (Odum and Kuenzler 1955) for each home range, based on the 95% isopleth, to evaluate whether our sample of relocations adequately described home range size for the period of interest. For purposes of comparison with past work, we also estimated the size of home range for each hawk with the 100% minimum convex polygon (MCP) method after discounting one obvious outlier for one bird. We used program RANGES V (Kenward and Hodder 1996) for all of the analyses related to home ranges.

We had color-marked breeding adults in the study area since 1994 (Boal 1997); thus, we knew the exact or minimum number of years that a male had occupied its home range. We examined the relationship between home range size (based on the 95% isopleth and the 100% MCP) and the number of years of residency with linear regression (Ramsey and Schafer 1997). We transformed size of home range (i.e., the response variable) with a log transformation because variability increased as the mean increased (Ramsey and Schafer 1997). Regression analyses were conducted in the JMP IN 3 Windows Version statistical package (SAS Institute Inc. 1996).

We overlaid the 95% isopleth for each home range onto a digital database coverage of land use categories in Tucson (Shaw et al. 1996). We queried the database for coverage of each category in each home range, compared the coverages with aerial photographs to assess accuracy, and corrected coverages in one home range. We then pooled the categories in all home ranges to generate a total estimate of the categories used by Cooper's Hawks (Thomas and Taylor 1990). The percentages of land use categories in each home range and in all home ranges combined were compared to the availability of the categories in a rectangular area that encompassed all home ranges (Thomas and Taylor 1990). These comparisons allowed us to examine habitat selection at the spatial scale of the home range (Johnson 1980). We also examined habitat selection by each hawk inside its home range by comparing the observed number of locations in each category to the number that would be expected if a hawk used each category in proportion to its occurrence within the home range. All comparisons of "use versus availability" (n = 10) were made with χ^2 Goodness-of-fit tests (Sokal and Rohlf 1995). We adjusted the level of alpha we considered significant for the Goodness-of-fit tests from 0.05 to 0.005 based on the Bonferroni adjustment (Sokal and Rohlf 1995). Goodness-of-fit tests were conducted in the Statistical Package for the Social Sciences (SPSS) Version 2 on MS Dosshell Version 2.78.

RESULTS

Home range size and overlap.—We radio-tagged 10 male Cooper's Hawks during the study and obtained sufficient relocations on 9 of them to estimate home range size (Table 1). Relocations (n = 657) of all hawks were spread throughout the day (05:00–09:00: 27%; 09:00–13:00: 24%; 13:00–17:00: 21%; 17:00–dark: 27%). Most relocations (79% of 513) away from the nest tree/grove were based on visual sightings. All 9 home ranges were relatively stable in size throughout the breeding season, and none increased more than 5% over the last 10 locations (Fuller and Snow 1988). Mean size of home ranges, based on the 95% isopleth, was 65.5 ha (median = 45.6 ha; range = 13.3–130.6 ha; Table 1). However, 90% of the relocations occurred, on average, within 33.9 ha (median = 30.6; range = 3.3–104.7 ha; Table 1). Only one pair of

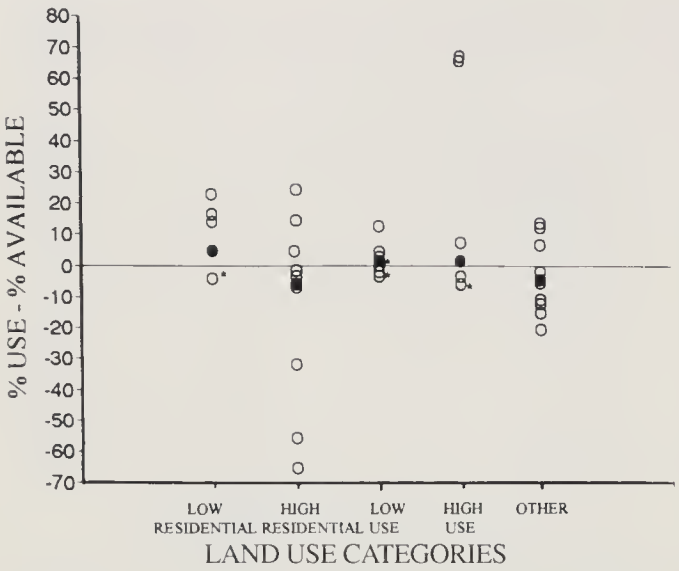

FIG. 2. Percent use minus percent available of land use categories in the home ranges of nine male Cooper's Hawks (○) and the total of all home ranges (●) in Tucson, Arizona, 1996–1997 (* indicates that more than one hawk is represented by a single ○). Percent available for each category was calculated from a rectangular 3618-ha area that encompassed all home ranges ($\chi^2 = 56.3$, 4 df, $P < 0.001$). Low Residential ≤ 7.6 residences per ha; High Residential ≥ 7.6 residences per ha; Low Use = cemeteries, neighborhood parks, and natural open space; High Use = golf courses, district and regional parks, and schools; Other = roadways, and commercial, agricultural, and industrial areas.

home ranges (San Carlos and Torino, Fig. 1) overlapped each other. The home range of the San Carlos male overlapped the home range of the Torino male by 14.2%, and the home range of the Torino male overlapped the home range of the San Carlos male by 10.6%. Size of home range, based on the adaptive kernal method (95% isopleth), decreased with the number of years that a male had occupied his territory [Table 1; linear regression: log of home range area = 2.28 − 0.31 × (years of residency); r^2 adjusted = 0.89; $F_{1,7} = 65.58$; $P < 0.001$]. The relationship between size of home range and years of residency was similar, but not as strong, when home range size was estimated with the MCP method [Table 1; linear regression: log of home range area = 2.33 − 0.27 × (years of residency); $r^2 = 0.51$; $F_{1,7} = 9.25$; $P = 0.019$].

Home range selection.—There was apparent selection by Cooper's Hawks for some land use categories when the combined home ranges of all nine hawks were compared to the area encompassing the home ranges (Fig. 2). For example, high density residential areas and commercial districts and roadways (i.e., "other") were present in the combined home ranges less than expected based on availability, and low density residential areas were present in the combined home ranges more than expected based on availability ($\chi^2 = 56.3$, 4 df, $P < 0.001$; Fig. 2). Percent of land use categories among individual home ranges, however, varied considerably (Fig. 2). Some home ranges were dominated by high density residential areas, whereas others were dominated by parks and golf courses (Table 2). No single land use category was consistently selected or avoided by all hawks when the composition of individual home ranges was compared to the composition of the area encompassing the home ranges (Fig. 2).

TABLE 2. Percentages of locations by land use categories[a] in home ranges of male Cooper's Hawks during the breeding season in Tucson, Arizona, 1996, 1997.

Nest	Percent of locations (percent of home range)				
	Low residential	High residential	Low use	High use	Other
Adams*[b]	0 (0)	100 (64.0)	0 (4.1)	0 (0)	0 (31.9)
Cooper*	0 (0)	100 (79.5)	0 (5.4)	0 (0)	0 (15.0)
Himmel Park*	0 (0)	13.4 (71.1)	0 (0.2)	86.6 (13.4)	0 (15.3)
Randolph North*	1.4 (19.9)	0 (0)	0 (6.0)	98.6 (74.2)	0 (0)
Reid Park*	0 (0)	0 (8.5)	0 (6.8)	100 (75.0)	0 (9.7)
San Carlos*	91.0 (27.0)	9.0 (58.2)	0 (7.0)	0 (1.3)	0 (6.5)
Swanway*	0 (0)	40.4 (62.1)	56.2 (10.4)	0 (0)	3.4 (27.5)
Terra Alta*	0 (0)	94.6 (89.7)	2.1 (0.2)	0 (0)	3.2 (10.1)
Torino*	1.8 (17.0)	78.6 (34.2)	19.6 (17.4)	0 (0)	0 (31.3)

[a] Low residential ≤7.6 residences per ha, High residential ≥7.6 residences per ha, Low use = cemeteries, neighborhood parks, and natural open space, High use = golf courses, district and regional parks, and schools, Other = roadways, and commercial, agricultural, and industrial areas.

[b] Asterisks denote that a significant difference ($P < 0.005$) was found between observed and expected frequencies of locations among land use categories (Goodness-of-fit test, Bonferroni correction). Categories with zero values were lumped to meet assumptions of the test.

Intra-home range selection.—Habitat selection inside individual home ranges also varied among hawks, but some patterns emerged. For example, all hawks avoided roadways, and commercial, agricultural and industrial areas (i.e., the "other" category) when they were present in their home ranges (Table 2). All but two hawks (Swanway and San Carlos) used either high density residential areas or regional parks and golf courses more than expected based on their availability (Table 2). The Swanway male predominantly used a small, neighborhood park and high density residential areas, and the San Carlos male used low density residential areas (Table 2).

DISCUSSION

Estimates of home range size for breeding Cooper's Hawks, based on nest density, range from 400 to 1800 ha (Craighead and Craighead 1956, Reynolds 1989). Estimates of home ranges during the breeding season, based on radio telemetry, vary from 784 ha for a male in a suburban area of Wisconsin (Murphy et al. 1988) to an average of 1206 ha for males in the Jemez Mountains of New Mexico (Kennedy 1989). The home ranges of male Cooper's Hawks in Tucson comparatively were small (65.5 ha).

Newton (1986) found that Sparrowhawks (*Accipiter nisus*) in Scotland became sedentary when prey animals were abundant and ranged widely when prey animals were scarce. We speculate that the abundance of prey in Tucson most likely accounts for the small home ranges we observed. Our speculation is supported by evidence that urban areas generally support a higher total density and biomass of birds than non-urban areas (e.g., in Tucson, Emlen 1974; elsewhere, Beissinger and Osborne 1982, Blair 1996, Marzluff et al. 1998). Furthermore, Mourning Doves (*Zenaida macroura*) and Inca Doves (*Columbina inca*) are the second and fourth most abundant birds in Tucson and their numbers are positively correlated with increasing housing density (Germaine et al. 1998). Doves also are abundant in parks and golf courses, and account for 84% of the identified prey (n = 121) at 45 Cooper's Hawks nests in Tucson (Boal 1997). We frequently observed prey captures and capture attempts in and near the nest tree and suggest that Cooper's Hawks do not need to range far from their nests to find food.

The home range sizes of Cooper's Hawks in Tucson, although relatively small, differed considerably among individuals. A variety of factors potentially influence home range size, including the abundance of prey, stage of the annual cycle, and age and sex of the hawk. Our data hint that there is a relationship between the size of home range and the number of years of residency. For example, all four of the largest home ranges (based on the adaptive kernal method, 95% isopleth), including the only two that overlapped, were occupied by new males. Lack of familiarity with their home ranges may have promoted more exploration by these males during hunting forays than males in more established home ranges. Increased efficiency in foraging with increasing age, especially in the first year of life, is common in birds (Wunderle 1991). Therefore, it seems reasonable to suggest that hawks, even as adults, become more efficient as they learn about a new area, and that this efficiency should increase most in the first year or two of residency.

Variation in the composition of individual home ranges when compared to the composition of the area that surrounded them suggests that male Cooper's Hawks in Tucson do not select home ranges on the basis of the land use categories we examined. Patterns of habitat use by Cooper's Hawks inside their home ranges also suggest that they are flexible in the types of urban environments they use. Within their home ranges, individual hawks usually were located more often than expected in either residential areas, regional parks and golf courses, or small, neighborhood parks. We speculate that because doves are abundant throughout Tucson (Germaine et al. 1998) individual preferences for where hawks spend their time, and thus where they likely hunt most frequently, may be influenced largely by location of the nest. Nests of Cooper's Hawks in Tucson usually are in groves of large, exotic trees [aleppo pine (*Pinus halepensis*) and *Eucalyptus* spp.] which are most common in older neighborhoods, city parks, golf courses, and cemeteries (Boal and Mannan 1998). Our findings contrast with the only other information about habitat selection by urban-dwelling Cooper's Hawks. Murphy and coworkers

(1988) found that the single male they tracked selected undeveloped woodlands and shrublands and avoided wooded residential areas and residential areas/businesses.

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